A study on contactless airborne transfer of textile fibres between different garments in small compact semi-enclosed spaces

Keywords: textile fibres; transfer; airborne; shedding; primary; secondary; contactless; evaluation

Abstract

Interpretation of fibre evidence at activity level requires extensive knowledge of all the possible transfer mechanisms that may explain the presence of fibres on a recipient surface of interest. Herein, we investigate a transfer method that has been largely understudied in previous literature: contactless transfer between garments through airborne travel. Volunteers were asked to wear UV-luminescent garments composed of different textile materials and situate themselves in a semi-enclosed space (elevator) for a pre-determined period of time with other participants, who wore non-luminescent recipient garments. The latter were then inspected for fibres using UV-luminescent photographic techniques. Results showed that contactless transfer between garments is possible. Indeed, a number of fibres were observed after most of the experiments. As many as 66 and 38 fibres were observed in the experiments involving cotton and polyester donor garments, compared to 2 and 1 fibres in those involving acrylic and wool donor garments, respectively. In this regard, the type of donor garment was found to be a significant factor. Multifactorial ANOVA supported these observations ($p < 0.001$) and further indicated a statistically significant influence of elevator door opening/closing ($p < 0.001$), people entering/exiting ($p = 0.078$) and the recipient garment ($p = 0.030$). Therefore, contactless transfer of fibres between garments can occur and can do so in (ostensibly) high numbers. This should be taken into consideration when interpreting fibre evidence at activity level and may have a major implication for the assignment of evidential values in some specific cases.

1.0 Introduction

Textile fibres are an important evidence type in forensic science and have proven utility in the investigation of a number of complex major crimes. Thanks to their ability to be easily transferred from one surface to another they enable associations of many different forms to be made, including links between people, locations and/or objects. Robust and efficient protocols to collect and examine fibre evidence currently exist [1-3]. Interpretation of observed findings, nonetheless, is still a very delicate procedure that requires sensible management of all available data, as well as careful consideration of many variables and influential factors. At activity level, in particular, a thorough understanding of all the transfer mechanisms that could potentially explain the presence of a group of questioned fibres on a recipient surface is needed, in order to correctly assign evidential values [4].

Pounds and Smalldon were the first to quantitatively investigate fibre transfer mechanisms. In a pioneering series of works published in 1975, they found that a large number of textile fibres could be shed from a donor garment and transferred to a recipient through a simple contact between them [5-7]. Consequently, they concluded that primary transfer between garments as a result of contact often provides the most likely explanation for their presence in the majority of situations. This is especially true in those cases where a large number of fibres is observed. Furthermore, they also found that fibres could subsequently be shed to a second recipient garment as a result of further additional contact events, thus providing preliminary evidence of the potential for secondary transfer (Figure 1). This additional mechanism was further investigated in-depth by Lowrie and Jackson [8], who confirmed secondary transfer as a viable transfer method for textile fibres but also demonstrated that it typically resulted in lower numbers of transferred fibres (1 – 11) in comparison to primary transfer (3 – 341).

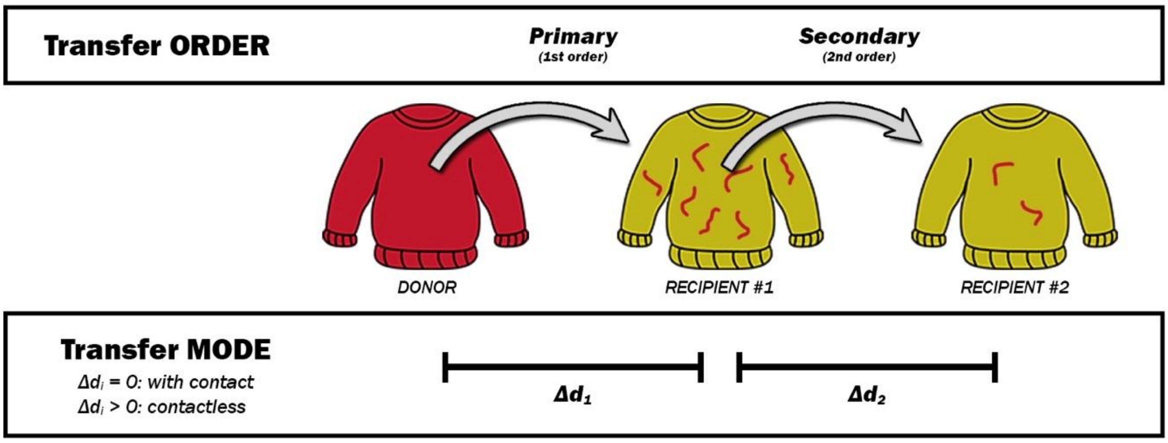

Figure 1: Overview of the two most common fibre transfer mechanisms.

Since these first investigations, many other studies have added to the body of knowledge of fibre transfer mechanisms and it is now widely accepted that textile fibres can potentially be transferred to a recipient surface in a number of ways during a criminal activity. Garment-to-garment, garment-to-surface and surface-to-garment transfers have all been documented [9-11]. Similarly, textile fibres were proven to be susceptible to serial transfer, through *n*-order subsequent transfer events: primary, secondary and even tertiary transfers have all been shown to be possible [5, 8, 12, 13]. Many different factors have been evidenced to affect all these transfer mechanisms, which include (amongst others) the donor garment, the recipient garment, the extent of contact and the length of contact.

Despite the extensive number of published works on this topic, most of them were solely aimed at the evaluation of transfer mechanisms by direct contact between the surfaces of interest. While this is admittedly the most represented scenario in typical forensic situations, it is not uncommon that the hypothesis of fibre transfer in the absence of contact is raised in real casework, in order to provide an alternative explanation for the presence of fibre evidence on a recipient surface. A typical case, for example, is when the accused claims that they collected the questioned group of fibres by airborne transfer, while having simply been in the same room or space as the victim. When presented with such defence scenarios, knowledge of mechanisms for the contactless transfer of textile fibres between surfaces of interest (e.g., garments) would be necessary for a proper interpretation of the findings.

Unfortunately, existing literature on contactless transfer of textile fibres is very limited. In this regard, some relevant studies were conducted by Moore [14] and Roux [15], although their main focus was to solely asses fibre contamination in and around purpose built forensic laboratory search rooms. Both authors found that textile fibres can become airborne during and following routine garment examinations and were able to travel distances of up to 3 m, before landing on a horizontal surface, such as the floor or a nearby bench. These studies demonstrate the potential for contactless transfer of textile fibres. Yet, no investigation to date has sought a quantitative assessment of contactless transfer mechanisms of textile fibres in simulated scenarios of forensic interest. As a consequence, there is a fundamental gap in the current state of knowledge on this topic and an overwhelming lack of published data to establish if, and to what degree, contactless transfer of fibres can occur from one (clothed) individual to another in a social (non-laboratory) environment.

The aim of this study was therefore to fill this gap and, more specifically, to investigate the contactless transfer of textile fibres between different garments in a compact, semi-enclosed space. For this purpose, elevators were specifically selected as test environments, since this type of environment would be potentially conducive to 'contactless' fibre transfer, thus providing a 'worst case scenario'. Experiments involved different garment compositions. Specifically, four different donor garments and two recipient garments were tested and contactless transfer between each possible combination of them was studied in replicate ($n = 6$). Each garment used was characterised in order to investigate the influence of composition, shedding and retention properties on the number of transferred fibres. Donor garments included those comprised of acrylic, cotton, polyester and wool fibres, while recipient garments were comprised of cotton or polyester fibres. Participants were asked to wear a specific donor or recipient garment, enter an elevator and remain inside for 10 minutes. The participants subsequently exited the elevator and the wearer of the recipient garment entered a second elevator, along with a third participant. This allowed an assessment of both primary and secondary contactless fibre transfer.

2.0 Materials and methods

2.1 Materials

All of the garments used in this work were purchased from various local shops. Donor garments included a 100% acrylic jumper (D1), 100% cotton long sleeved top (D2), 100% polyester fleece (D3) and 100% wool jumper (D4). These were specifically chosen for their differing propensity to shed fibres and the regularity with which the fibre types are encountered in casework. Recipient garments included different 100% cotton long sleeved tops (R1) and 100% polyester fleeces (R2). A breakdown of the garments and their properties is provided in Table 1.

Table 1: Characteristics of the garments used in this study

	Fibre type	Colour under UV light	Garment structure	Cross-section	Diameter (µm) (mean ± std dev; n=10)	Length (mm) (mean ± std dev; n=10)	Shedability (per 1 cm^2) (mean ± std dev; n=5)
D1	Acrylic	Green	Knitted, open	Bean	24.5 ± 4.95	12.7 ± 14.08	3 ± 1
D2	Cotton	Yellow	Knitted, open	N/A	n.m.	1.2 ± 1.03	149 ± 68
D3	Polyester	Orange	Fleece	Round	12.6 ± 2.97	1.8 ± 1.70	70 ± 15
D4	Wool	Pink	Knitted, open	N/A	30.1 ± 9.93	18.9 ± 12.58	4 ± 1
R1	Cotton	None	Knitted, open	N/A	n.m.	n.m.	n.m.
R2	Polyester	None	Fleece	Round	n.m.	n.m.	n.m.

n.m.: not measured

A desirable property for the donor garment was that their fibres fluoresced under UV light as, following transfer, this facilitated identification, counting and monitoring using luminescence photography. The fibres of garments D2 and D4 were naturally fluorescent as a manufacturing characteristic. This was not the case for garments D1 and D3, which were therefore dyed in the laboratory with different coloured UV-fluorescent dyes. This was carried out using commercially available *Dylon* dyes, according to manufacturer instructions. As a result, each donor garment fabric had different UV fluorescent properties, which avoided mistaken identity and ensured accurate counting. Recipient garments were intentionally black (and non-fluorescent), in order to provide contrast and aid fluorescent searching for target fibres.

2.2 Characterisation of the donor garments

In order to further investigate the correlation between donor garment properties and the number of fibres transferred, they were characterised in terms of their general structure, fibre characteristics (i.e., cross-section, diameter, length) and shedability. Garment structure and fibre characteristics were assessed using microscopy. Using phytohistol, a sample of fibres from each garment was mounted onto glass slides and a glass cover slip placed over the top. Fibre measurements were taken using a confocal *Leica DM5000 B* microscope coupled with *Image-Pro Analyzer 7.0* software, at magnifications between x5 and x40. The length of a fibre was measured by following the fibre from end to end and the diameter across its full width using the free roam drawing tool. 10 randomly selected fibres were measured per sample.

To assess the shedability, a single piece of *J-Lar*™ tape was lightly placed on to the front of the garment and firmly pressed along its length once, as is common practice by some UK forensic providers. The *J-Lar*™ was then removed from the garment and placed onto a clear acetate sheet. A 1 x 1 cm square was drawn roughly in the centre of the tape, through manual selection. The number of fibres within the square that originated from the garment was counted with the aid of brightfield microscopy, using a *Leica S6E*^{TM} low power stereomicroscope (magnification x6.3 - x40).

2.3 Experimental set-up

Both primary and secondary contactless transfer was assessed, starting from the same donor garment. Each experiment involved three participants adopting different roles, i.e. a donor, a primary recipient and a secondary recipient (Figure 1). The donor participant was asked to wear a particular donor garment. The type (i.e. cotton or polyester) of recipient garment was kept constant within a given experiment and, as such, the primary and secondary recipients both wore the same garment type, albeit separate garments. Two different elevators were used. Both were situated in a university building and measured 1.3 m x 1.7 m x 2.3 m (total volume: 5.0 m^3).

The donor participant was asked to enter one of the elevators and occupy one of the far corners. The primary recipient wearer entered the elevator on another floor and stood diagonally across from the donor, approximately 2 m apart; they both remained in position for 10 minutes before exiting separately on different floors. The primary recipient garment was then immediately photographed *in-situ* (front and back) with the aid of a UV light source. Next, the primary recipient wearer entered a second elevator and following exactly the same methodology as just described was joined by the wearer of the secondary recipient garment. After 10 minutes, the secondary recipient wearer left the elevator and photographed their garment *in-situ* as per the primary recipient garment. For simplicity, the entire experimental procedure is depicted in Figure 2.

Primary and secondary transfer experiments were repeated six times for each of the four donor garments, resulting in a total of 48 experiments. Whilst the experiments were taking place in the elevator, the elevator operated as normal and other non-participating people were allowed to enter and exit as they would usually do. The number of people entering/exiting the elevator during the 10-minute period was recorded, as was the number of times the elevator doors opened/closed.

On completion of the transfer experiments, the wearers of the secondary recipient garments carried on with their normal activities whist still wearing the garment. At time intervals of 0.5, 1.0, 1.5 and 2.0 hours the recipient garment was again photographed *in-situ* as before. Each experiment ended when no transferred fibres remained.

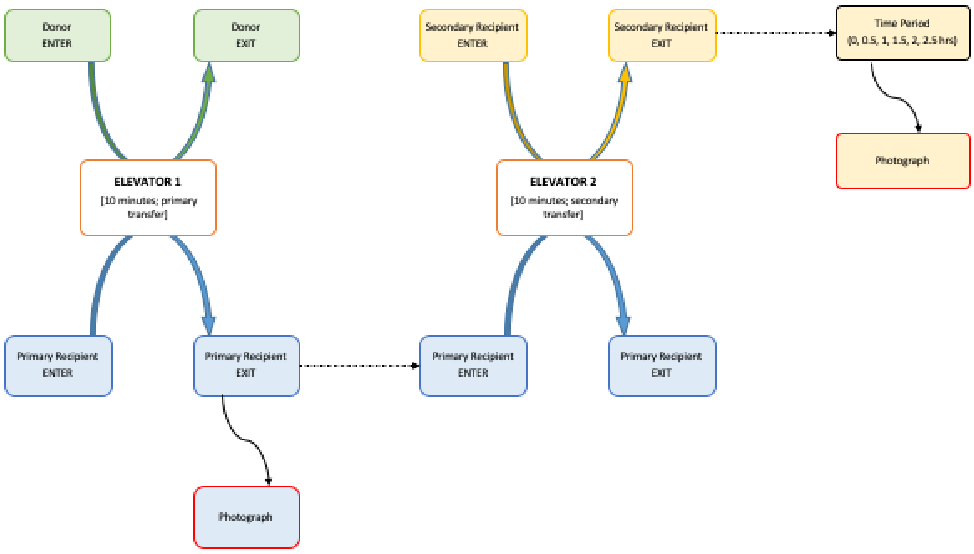

Figure 2. Schematic of the experimental procedure

2.4 Fibre counting

As target fibres were fluorescent, post-transfer recipient garments were examined using a UV source and photographed in a darkened room. Photographs were taken using a *Canon EOS 5D Mark II* camera with *Canon EF 28mm 1:2.8 lens*, using ISO 6400, shutter speed 1/4 and aperture F3.2 settings, using the UV source *Crime-Lite 42S*^{TM} (350 – 380nm). To minimize background reflection *Ultra Black* paper from *Creativity Backgrounds (Daler*

Rowney Ltd) was mounted behind the subject. To ensure photographs were comparable/reproducible, the camera was mounted on a *GITZO* tripod attached with a *360 Precision Absolute* MK2 and the *Crime-Lite* was clamped using a *Manfrotto 244 RC Variable Friction Arm*. The garment wearer stood on a position marked 'X' and manually took photographs (front and back) of themselves using a *Hahnel HRC280* remote shutter release. No other person was present in the dark room when the photographs were taken. The number of target fibres was manually counted from the images.

Strict anti-contamination measures were imposed to minimise the risk of cross-contamination between experiments. Donor, primary and secondary recipient garments were individually stored inside paper bags in separate laboratories. Immediately prior to an experiment, the recipient garments were examined using a UV torch to ensure they were absent of target fibres.

2.5 Statistical analysis

Multifactorial analysis of variance (ANOVA) was applied in order to evaluate the effects of the different variables monitored during the experiments. These were the composition of the donor and recipient garments (controlled variables), as well as the number of times the elevator doors opened/closed and the number of people who entered/exited (uncontrolled variables). A model with main effects without interactions was built on data using a generalised linear model with a Poisson distribution. Pairwise comparison (Tukey method) was additionally used to assess statistically significant differences between donor groups.

Statistical modelling was performed only on data from primary contactless transfer. Attempts to model data from the secondary contactless transfer experiments were unsuccessful due to the low number of observations that differed from 0, resulting in model instability. Statistical analysis was performed using the open source platform *R,* version 3.5.3 "Great Truth".

3.0 Results

3.1 Primary contactless transfer

Eight scenarios aimed at evaluating the possibility of primary contactless transfer between textiles were investigated using each of the four donor garments (i.e., cotton, polyester, acrylic and wool) coupled with one of the two different recipient garments (i.e., cotton and polyester). Each scenario was replicated six times, resulting in a total of 48 experiments. Primary contactless transfer of fibres occurred in 67% of these cases (32 of 48 experiments) and, more specifically, in 100% of the experiments involving cotton as the donor garment (12 of 12), 100% of the experiments involving polyester (12 of 12), 42% of the experiments involving acrylic (5 of 12) and 25% of the experiments involving wool (3 of 12). A summary of the number of fibres observed is reported in Table 2 and depicted in Figure 3.

Table 2: Summary of the results observed after the primary transfer experiments.

	RECIPIENT GARMENTS											
	Cotton (R1)				Polyester (R2)				**Combined results**			
DONOR GARMENTS	Min	Max	Median	Mean	Min	Max	Median	Mean	**Min**	**Max**	**Median**	**Mean**
Acrylic (D1)	0	1	0.0	0.17	0	2	1.0	1.00	**0**	**2**	**0.0**	**0.58**
Cotton (D2)	13	60	17.0	26.70	17	66	43.5	44.50	**13**	**66**	**36.0**	**35.58**
Polyester (D3)	15	32	27.0	25.50	8	35	12.0	16.80	**8**	**35**	**23.0**	**21.17**
Wool (D4)	0	1	0.5	0.50	0	0	0.0	0.00	**0**	**1**	**0.0**	**0.25**
Combined results	**0**	**60**	**7.0**	**13.21**	**0**	**66**	**5.0**	**15.58**	**0**	**66**	**5.0**	**14.40**

From the analysis of the results it was evident that, under the chosen experimental conditions, the donor garment made from cotton transferred the highest number of fibres (median: 36.0, mean: 35.58), followed by (in decreasing order) those made from polyester (median: 23.0, mean: 21.17), acrylic (median: 0.0, mean: 0.58) and wool (median: 0.0, mean: 0.25). The type of donor garment was therefore found to be an important factor in the contactless transfer of fibres.

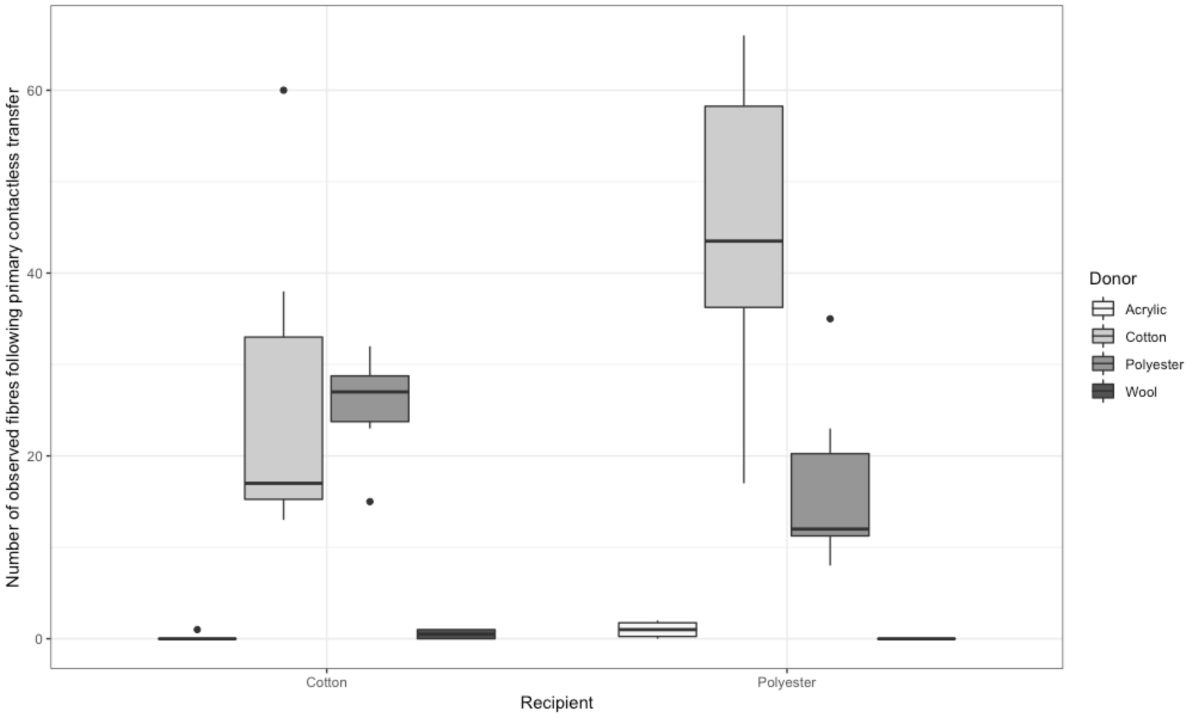

Figure 3: Boxplots of the number of fibres observed after the primary transfer experiments as a function of the composition of the donor and recipient garments.

There was no clear difference between the number of fibres observed on the recipient garments made of polyester (median: 5.0, mean: 15.58) compared with that made of cotton (median: 7.0, mean: 13.21). However, further inspection of the data revealed notable differences depending on which donor garment was used (Figure 3). For example, higher numbers of fibres were consistently observed on the cotton recipient garments if the polyester garment had been used as the donor (median: 27.0, mean: 25.50), in comparison with experiments in which the cotton garment was the donor (median: 17.0, mean: 26.70). The inverse was true for experiments in which the polyester recipient garments were used: in this case, the number of fibres observed was lower if the polyester garment was the donor (median: 43.5, mean: 44.50), compared with the situation in which the cotton garment was donor (median: 12.0, mean: 16.80). These observations thus suggested an interaction effect of some kind between the fibres that comprised the donor garment and the recipient garments and also supported the hypothesis that the number of fibres transferred could vary greatly depending on the specific situation and the recipient garment involved.

ANOVA was applied, in order to further investigate the data. Results showed that the compositions of the donor and recipient garments had statistically significant effects on the numbers of observed fibres, even if the effect of the recipient was less important than the effect of the donor ($p = 0.030$ and $p < 0.001$, respectively) (Table 3). This largely supported the conclusions previously inferred from the descriptive analysis.

Post-hoc pairwise comparisons of the model coefficients disclosed further differences between donor groups, mainly between cotton and wool/acrylic ($p < 0.001$) and between polyester and wool/acrylic ($p < 0.001$) (Table 3). As might be expected based on the low number of fibres transferred, there was no significant difference between wool and acrylic donors (p = 0.544). However, the analysis did reveal a significant difference between the two most influential donors, i.e. cotton and polyester (p < 0.001).

Table 3: Analysis of effects (ANOVA) and pairwise comparisons (*italics*) of primary transfer experimental data.

Variable	df	Deviance	p-value[a]
Donor garment	**3**	**899.44**	**< 0.001 (***)**
Acrylic - Cotton			*< 0.001(***)*
Acrylic – Polyester			*< 0.001(***)*
Acrylic – Wool			*0.544*
Cotton – Polyester			*< 0.001(***)*
Cotton – Wool			*< 0.001(***)*
Polyester - Wool			*< 0.001(***)*
Number of door openings/closing	**1**	**47.22**	**< 0.001 (***)**
Recipient garment	**1**	**4.71**	**0.030 (*)**
Cotton – Polyester			*0.072* (**.**)
Number of entering/exiting people	**1**	**3.11**	**0.078 (.)**

[a] Significance codes: ‘***’ $p < 0.001$, ‘**’ $p < 0.01$, ’*’ $p < 0.05$, ‘**.**’ $p < 0.1$

Although variables not directly controlled in this study, the number of times the elevator doors opened/closed and the number of people who entered/exited the elevator during each experiment were recorded and analysed using ANOVA (Table 3). Results demonstrated that both variables had a significant effect on the number of observed fibres following the experiments and, therefore, could potentially influence the contactless transfer of fibres. This may be due to an increase of air movement [16]. Moreover, the effect of the number of opening/closing of elevator doors was considerably less important than the number of entering/exiting of people (p = 0.078 and p < 0.001, respectively). The scatter plots of the number of observed fibres against both variables were further studied and showed that, actually, there was a noticeable negative correlation between the number of observed fibres and the opening/closing of elevator doors, i.e. fewer fibres were transferred with an increase in elevator doors openings/closings (Figure 4) irrespective of the donor or recipient garments.

No clear linear trend was highlighted between the number of observed fibres and the number of people entering/exiting.

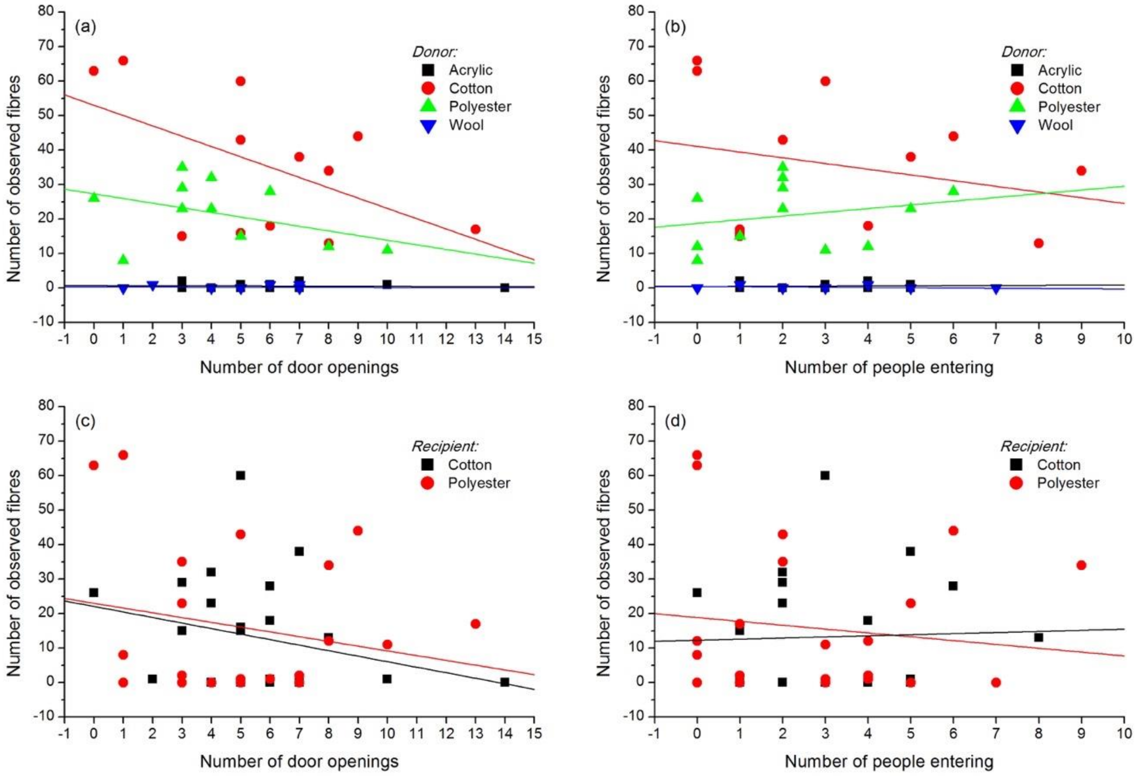

Figure 4: Scatter plots of the number of fibres observed after the primary transfer experiments against the number of door opening/closing and the number of people entering/exiting the elevator grouped by the composition of the (a-b) donor and (c-d) recipient garments.

3.2 Secondary contactless transfer

A primary contactless transfer was observed in 32 of the 48 experiments conducted (see previous sub-chapter). Therefore, these 32 cases were further investigated for the possibility of secondary contactless transfer. More specifically this entailed 12 experiments that concerned cotton and polyester as the initial donor garments, 5 experiments using the acrylic donor and 3 using the wool donor. Secondary contactless transfer of fibres occurred in 41% of these cases (13 of 32 experiments) and, more specifically, in 58% of the experiments involving cotton fibres (7 of 12) and 50% of those involving the polyester fibres (6 of 12); on no occasion was contactless secondary transfer of wool or acrylic fibres observed. A summary of the number of fibres observed is reported in Table 4 and depicted in Figure 5.

Table 4: Summary of the results observed after the secondary transfer experiments.

	RECIPIENT GARMENTS											
	Cotton (R1)				Polyester (R2)				**Combined results**			
DONOR GARMENTS	Min	Max	Median	Mean	Min	Max	Median	Mean	**Min**	**Max**	**Median**	**Mean**
Acrylic (D1)	0	0	0.0	0.00	0	0	0.0	0.00	**0**	**0**	**0.0**	**0.00**
Cotton (D2)	0	8	2.5	3.17	0	4	0.0	1.00	**0**	**8**	**2.0**	**2.01**
Polyester (D3)	0	2	0.0	1.17	0	6	2.5	2.83	**0**	**6**	**1.0**	**2.00**
Wool (D4)	0	0	0.0	0.00	0	0	0.0	0.00	**0**	**0**	**0.0**	**0.00**
Combined results	**0**	**8**	**0.0**	**1.73**	**0**	**6**	**0.0**	**1.44**	**0**	**8**	**0.0**	**1.58**

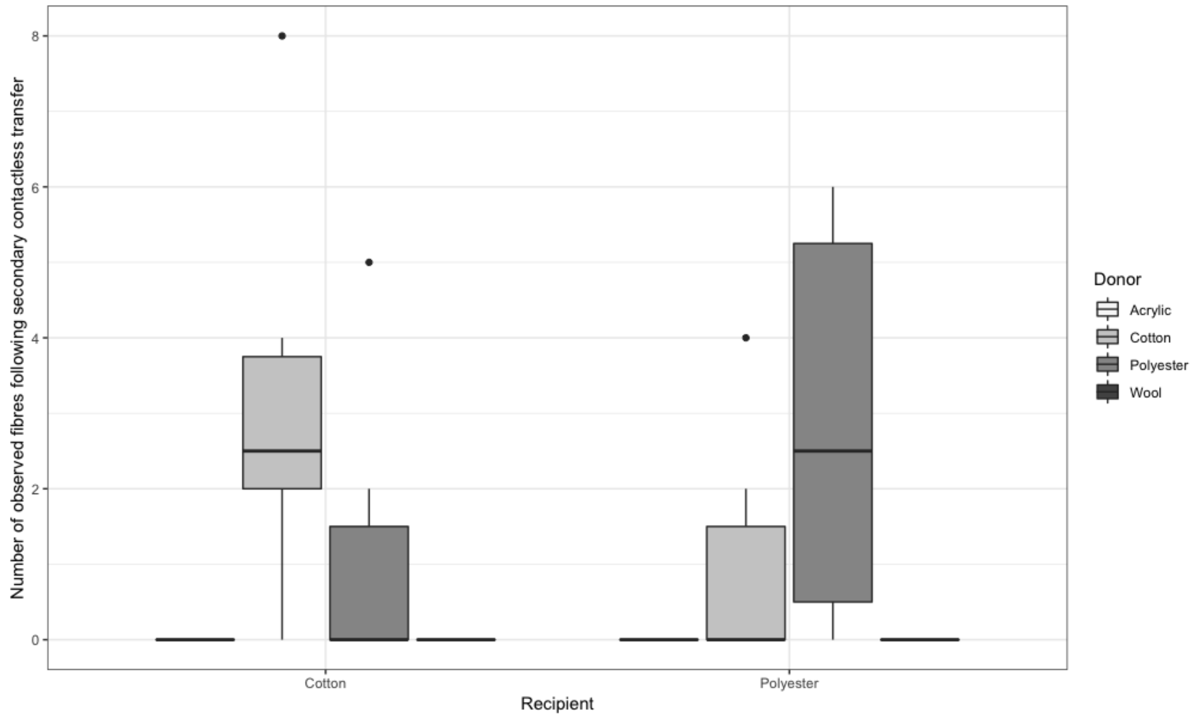

Figure 5: Boxplots of the number of fibres counted after the secondary transfer experiments as a function of the composition of the donor and recipient garments.

Again, differences in the number of fibres transferred were observed between the types of fibre, as originating from their respective donor garments. These differences were broadly consistent with those observed for primary transfer experiments. Indeed, cotton fibres displayed the largest degree of secondary transfer (median: 2.0, mean: 2.01) compared with polyester (median: 1.0, mean: 2.00), even if their relative difference was less pronounced than in primary transfer experiments. No acrylic or wool fibres were observed on the secondary recipient garments (median: 0.0, mean: 0.00), likely owing to the small pool of fibres available for (secondary) transfer following primary transfer (max = 2). No remarkable difference was noticed between the different recipient garments.

As before, ANOVA was attempted, but it did not produce any reliable results, due to the instability of the model resulting from the low number of data points for certain experiments. Consequently, statistical significance could not be investigated. Nonetheless, the scatter plot showing the numbers of fibres observed were again studied for noticeable trends. Although not as prominent as for primary transfer experiments, a slight negative correlation between the number of observed fibres and the number of opening/closing of elevator doors was again observed (Figure 6). On the contrary, no apparent linear trend was evident here between the number of observed fibres and the number of people entering/exiting the elevator, as with primary contactless transfer.

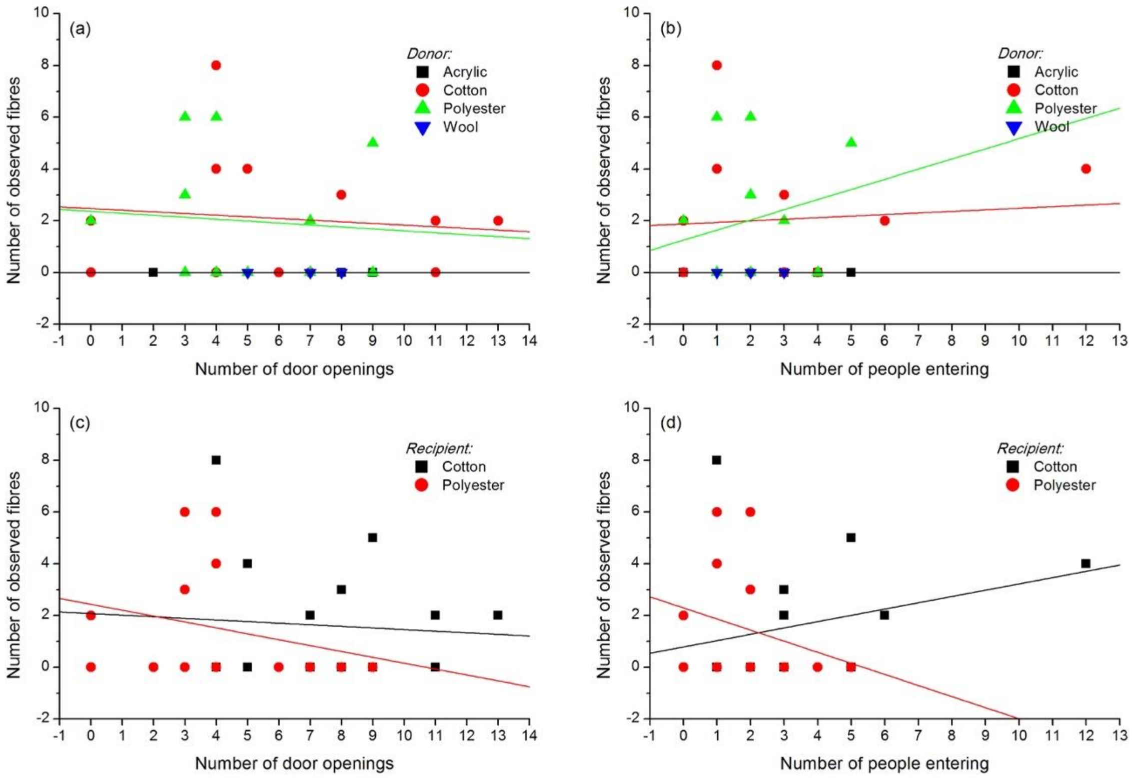

Figure 6: Scatter plots of the number of fibres observed after the secondary transfer experiments against the number of door opening/closing and the number of people entering/exiting the elevator grouped by the composition of the (a-b) donor and (c-d) recipient garments.

For completeness, the persistence of the cotton and polyester fibres that had undergone secondary transfer was tracked over time. In seven of the 13 experiments, all fibres were lost within 30 minutes and, for the remaining six experiments, a maximum of five fibres remained. On two occasions a single fibre remained after 60 minutes but they were both then lost within 120 minutes.

4.0 Discussion

Contactless transfer of textile fibres has been demonstrated in small, compact and semi-enclosed spaces (elevators) that simulated real situations. In particular, up to 66 fibres were transferred in a single primary transfer experiment and, on one occasion, 8 fibres (half of those transferred through primary contactless transfer) were further transferred through secondary contactless transfer. Different influential variables were studied and shown to have a noticeable effect on the number of observed fibres on the different recipient garments. These variables were, in order of their relative importance, i) the donor garment, ii) the number of door opening/closing, iii) the recipient garment and iv) the number of people entering/exiting.

The donor garment was found to have the most influential effect on the number of transferred fibres observed on the recipient garments, supporting its fundamental role in the mechanism of contactless transfer. The underlying principle(s) for this may be multifaceted. The number of fibres transferred is contingent on how susceptible the fibres themselves are to (1) become airborne and (2) remain airborne (as if they immediately fell to the ground no transfer could occur). Their ability to do so will, in turn, be dependent on a number of intrinsic characteristics of both the garment and the fibres themselves, such as the textile composition and structure, and type of fibre and their dimensions. The experimental design of this study did not fully allow an extensive analysis of the direct effect of each of these influential factors on the mechanism of contactless transfer. Nonetheless, an obvious distinction was observed between garments comprised of cotton/polyester versus acrylic/wool, supporting the hypothesis that the donor composition, fibre type and size may be very important contributing factors. Indeed, the dimensions of the fibres comprising the donor garments support this in that the longer, wider fibres (wool, acrylic) were much less likely to be contactlessly transferred in comparison with shorter, thinner fibres (cotton, polyester), advocating the importance size/dimensions of the fibre themselves [17, 18]. A very strong positive correlation was expectedly observed between the amount of fibres observed on the recipient garments following primary transfer and the shedability of the donor garment (Figure 7), underlying the direct and significant role of the propensity of the garment to shed its constituent fibres on the transfer mechanism [19].

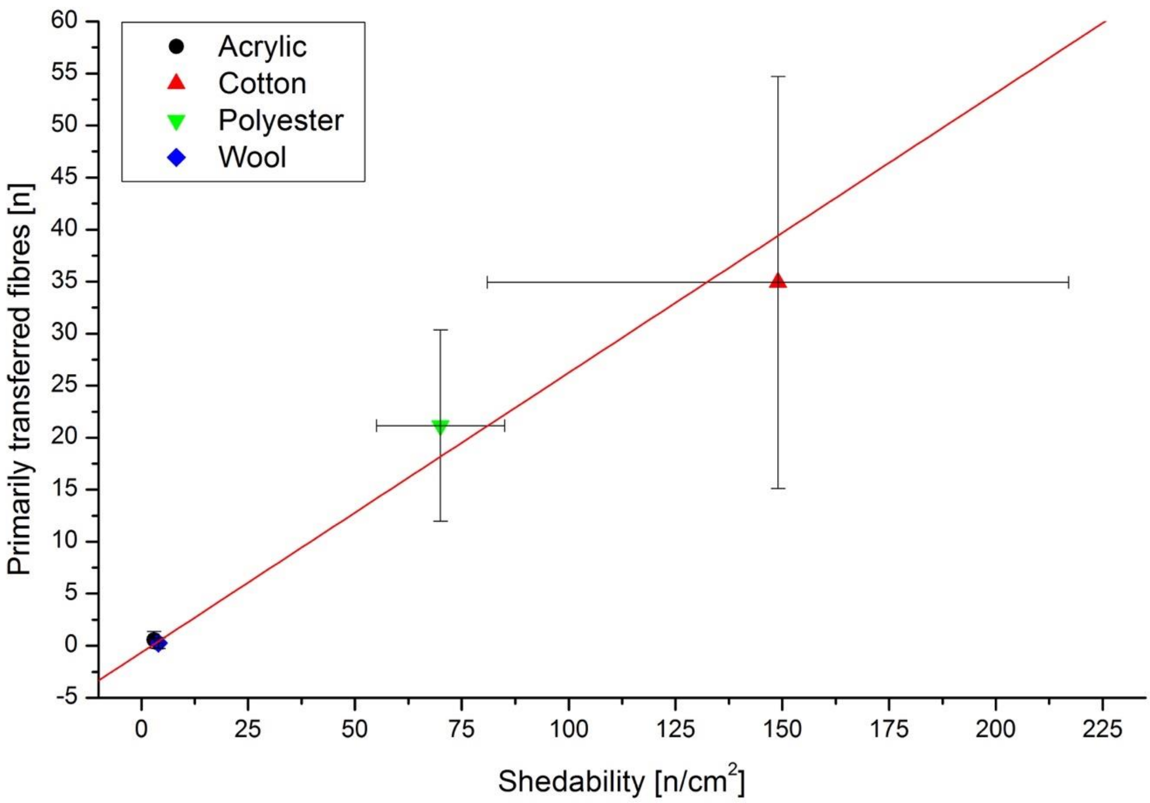

Figure 7: Plot of the number of fibres observed after primary contactless transfer against the shedability of the donor garment. A clear relationship could be established between the two variables.

The importance of the fibres themselves, opposed to the donor garment and its structure, on contactless transfer may be further evidenced through the influence of the recipient garment and the effect of air movement. In contrast to fibre transfer through contact, which involves a degree of pressure, contactless fibre transfer (and subsequent persistence) relies solely on the relationship between the transferring fibre and the recipient surface. The negative correlation between the number of observed fibres on recipient garments and the opening/closing of the elevator doors may further substantiate this theory. This is supported through previous studies which have demonstrated that air movement keeps fibres in the air [14, 15] and thus may affect weak interactions. Such interactions between the composition of the donor and recipient garment were indeed found to be a notable factor affecting contactless transfer and, in this study, more so than the exclusive retentive properties of the recipient garment. The polyester recipient garment, being a fleece, had a rougher texture than the cotton garment, and as such was expected to be more retentive [16, 20]. However, the effect was not as pronounced as may have been anticipated, with this apparent disparity perhaps being explained by both garments having inherently retentive surfaces. Arguably, a greater difference between the retentive properties of the recipient garments may have resulted in a more distinct variance in the number of fibres observed.

Comparison of the results of this study with the previous literature regarding fibre transfer involving contact, and in particular the original work of Pounds and Smalldon [5] and Lowrie and Jackson [8], revealed both similarities and differences between the transfer mechanisms. A clear similarity was the significant role the donor and recipient variables have on the transfer of fibres both with, and in the absence of, contact. On the contrary, the quantities of fibres transferred as a result of physical contact are far in excess of the order of quantities seen in this study (allowing for differences in experimental design). This was somewhat expected given the weaker forces involved in the process (physical contact vs air movement). It may therefore be reasonable to conclude that the quantity of fibres transferred as a result of contactless transfer, despite being (ostensibly) high in the case of cotton/polyester, are much lower than that which would be expected from a transfer involving contact. Interestingly, the order of fibre quantities transferred, particularly for acrylic and wool fibres, are more akin with that previously observed as a result of secondary contact [8]. Thus, there is a danger that similar numbers observed in casework could be misinterpreted in the absence of detailed case specific information (i.e. the framework of circumstances) when evaluating activity level propositions.

The results of this study demonstrate that contactless transfer should be considered as a viable transfer mechanism in the interpretation of fibre evidence, but its importance, and thus, contribution, to activity level evaluation is dependent upon the specific case at hand. In cases where a high number of transferred fibres have been found, the contribution of contactless transfer to that finding is likely to be negligible and thus would be of limited importance in any evidential interpretation. However, for those cases in which a small number of transferred fibres are recovered contactless transfer should be a greater consideration, particularly if case circumstances involve a passive interaction between a suspect and victim.

It is important, too, to emphasise that, not only were the experiments in this study specifically designed to maximise the potential for contactless fibre transfer, but that fibre transfer was recorded within minutes of transfer, providing a reference point at t = 0. As such, the results of this study should be considered within the setting in which the experiments were conducted, and expectations altered accordingly. Real case situations will differ in terms of the area/environment in which contactless transfer is alleged to have taken place. As an environment becomes larger and/or more open than used in this study, the likelihood of fibres being transferred in large numbers as a result of contactless fibre transfer is likely to be concomitantly reduced, although further studies would be needed to evidence this. Furthermore, in real casework, exhibits are likely to be seized sometime after the incident, thus reducing the number of transferred fibres expected to be recovered.

5.0 Conclusions

In this study, the potential of fibre movement between different garments through contactless airborne mechanisms has been assessed for small, compact and semi-enclosed spaces, such as elevators. It was proven, not only that this transfer mechanism is fully possible in authentic forensic scenarios (both as primary and secondary transfer), but also that the number of fibres transferred could be particularly significant for certain types of textile materials (such as cotton and polyester) and, importantly, comparable to other transfer mechanisms involving contact. Therefore, the potential for contactless fibre transfer should be carefully assessed in real casework and appropriately taken into account in the interpretation of findings at activity level. In this respect, the authors believe that the empirical data provided in this work may constitute a reference point.

Conflict of interest

There are no conflicts to declare.

Bibliography

[1] ENFSI, European Textile and Hair Group, Best Practice Guideline for the Forensic Examination of Fibres, (2nd Ed.), 2011.

[2] ASTM E1492-11, Standard Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory, ASTM International, West Conshohocken, PA, 2017.

[3] ASTM E2228-19, Standard Guide for Microscopical Examination of Textile Fibers, ASTM International, West Conshohocken, PA, 2019.

[4] C. Champod, F. Taroni, Bayesian framework for the evaluation of fibre transfer evidence, Science & Justice 37(2) (1997) 75-83. https://doi.org/10.1016/S1355-0306(97)72151-8

[5] C.A. Pounds, K.W. Smalldon, Transfer of fibers between clothing materials during simulated contacts and their persistence during wear. 1. Fiber transference, Journal of the Forensic Science Society 15(1) (1975) 17-27. https://doi.org/10.1016/s0015-7368(75)70932-5

[6] C.A. Pounds, K.W. Smalldon, Transfer of fibers between clothing materials during simulated contacts and their persistence during wear. 2. Fiber persistence, Journal of the Forensic Science Society 15(1) (1975) 29-37. https://doi.org/10.1016/S0015-7368(75)70933-7

[7] C.A. Pounds, K.W. Smalldon, Transfer of fibers between clothing materials during simulated contacts and their persistence during wear. 3. Preliminary investigation of mechanisms involved, Journal of the Forensic Science Society 15(3) (1975) 197-207. https://doi.org/10.1016/s0015-7368(75)70933-7

[8] C.N. Lowrie, G. Jackson, Secondary transfer of fibers, Forensic Science International 64(2-3) (1994) 73-82. https://doi.org/10.1016/0379-0738(94)90215-1
[9] C. Roux, J. Chable, P. Margot, Fibre transfer experiments onto car seats, Science & Justice 36(3) (1996) 143-151. https://doi.org/10.1016/S1355-0306(96)72589-3
[10] R. Palmer, H.J. Burch, The population, transfer and persistence of fibres on the skin of living subjects, Science & Justice 49(4) (2009) 259-264. https://doi.org/10.1016/j.scijus.2009.02.008
[11] D. Sneath, H. Tidy, B. Wood, The transfer of fibres via weapons from garments, Forensic Science International (Online) 301 (2019) 278-283. https://doi.org/10.1016/j.forsciint.2019.05.027
[12] C.B.M. Kidd, J. Robertson, The transfer of textile fibers during simulated contacts, Journal of the Forensic Science Society 22(3) (1982) 301-308. https://doi.org/10.1016/S0015-7368(82)71496-3
[13] R. Palmer, K. Sheridan, J. Puckett, N. Richardson, W. Lo, An investigation into secondary transfer—The transfer of textile fibres to seats, Forensic Science International 278 (2017) 334-337. https://doi.org/10.1016/j.forsciint.2017.07.035
[14] J.E. Moore, G. Jackson, M. Firth, Movement of fibers between working areas as a result of routine examination of garments, Journal of the Forensic Science Society 24(4) (1984) 394-394. https://doi.org/10.1016/S0015-7368(86)72534-6
[15] C. Roux, J. Huttunen, K. Rampling, J. Robertson, Factors affecting the potential for fibre contamination in purpose-designed forensic search rooms, Science & Justice 41(3) (2001) 135-144. https://doi.org/10.1016/S1355-0306(01)71878-3
[16] A. Bucknell, T. Bassindale, An investigation into the effect of surveillance drones on textile evidence at crime scenes, Science and Justice 57(5) (2017) 373-375. https://doi.org/10.1016/j.scijus.2017.05.004
[17] R.R. Bresee, P.A. Annis, Fiber transfer and the influence of fabric softener, Journal of forensic sciences 36(6) (1991) 1699-1713. https://doi.org/10.1520/JFS13193J
[18] A. Coxon, M. Grieve, J. Dunlop, A method of assessing the fiber shedding potential of fabrics, Journal of the Forensic Science Society 32(2) (1992) 151-158. https://doi.org/10.1016/S0015-7368(92)73064-3
[19] L. Skokan, A. Tremblay, C. Muehlethaler, Differential Shedding: A Study of the Fiber Transfer Mechanisms of Blended Cotton and Polyester Textiles, Forensic Science International (2020) 110181. https://doi.org/10.1016/j.forsciint.2020.110181
[20] H.G. Scott, The Persistence of Fibres Transferred During Contact of Automobile Carpets and Clothing Fabrics, Canadian Society of Forensic Science Journal 18(4) (1985) 185-199. https://doi.org/10.1080/00085030.1985.10757393